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Variability in greenhouse gas emissions, fossil energy consumption and farm economics in suckler beef production in 59 French farms

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ABSTRACT

Efforts to assess the environmental performances of beef production systems often culminate in mitigation strategies without factoring in farm economics. The objective of this study was to co-assess the environmental impacts and economic performances of French suckler-beef production systems based on commercial farm data. We coordinated a technical–economic survey on 59 Charolais suckler-cattle farms in order to calculate GHG emissions and non-renewable energy (NRE) consumption over the years 2010 and 2011. Using real-world data from a farm network instead of modeled or experimental data enabled us to analyze the variability of the results and its determinants. The main variables impacting GHG emissions and NRE consumption per kg of beef (live weight) produced are (i) animal productivity (kg of live weight produced per LU), (ii) farm size (area and herd), and (iii) degree of specialization in beef production (share of cattle revenue in total farm revenue). The large, diversified farms (mixed crop–livestock farming systems) have a more negative environmental impact than the moderate-sized, specialized (beef production) farms. Animal productivity performances decrease with increasing herd size, and inputs use is below-optimal in the most strongly diversified farms. A comparison of the group of farms with the lowest and highest GHG emissions per kg beef (50% difference on GHG emissions per kg of live weight) confirmed these correlations. Through better animal productivity performances and lower use of inputs, the less-GHG-emitting farms also generate higher income per worker (+30%) while consuming less NRE. Our findings argue against the idea that size and diversification bring economic and environmental economies of scale and scope in suckler-beef production systems.

1. Introduction

In 2006, as the climate change debate was raging, livestock farming was singled out as a major driver of greenhouse gas (GHG) emissions (Steinfeld et al., 2006). The French GHG emissions inventory (CITEPA, 2011) shows that agriculture, excluding emissions related to energy consumption (fuel, electricity), accounts for 19% of national emissions. Methane (CH_4) is the top emission from agriculture (42% of GHG emissions from the agriculture sector) and is specifically and exclusively due to livestock farming, chiefly ruminants (enteric fermentation and manure management). Nitrous oxide (N_2O) emissions (58% of emissions from agriculture) are due to nitrogen fertilizers and livestock waste effluent spread on agricultural soil, together with nitrogen leaching. The fuel and electricity consumption on-farm accounts for 2.1% of total French carbon dioxide (CO_2) emissions.

Against this backdrop, a number of livestock system impact assessment studies have been led adopting the life cycle analysis (LCA) approach (Vries et al., 2010). A key focus of much of this research has been the quantification of GHG emissions from livestock systems, both at macro-scale (Leip et al., 2010; Weiss and Leip, 2012) and at dairy or suckler beef production scale.

LCA assessments of suckler beef production (Place and Mitloehner, 2012) are primarily based on farm model data (Crosson et al., 2011). These farm models represent one of more production systems widely encountered in the target country or region under study, and have been used to assess the environmental impacts of suckler beef production systems in Canada (Beauchemin et al., 2010), Ireland (Foley et al., 2011), the USA (Pelletier et al., 2010), Australia (Ridoutt et al., 2011), and France (Veysset et al., 2010). However, very few studies have been carried out using actual on-farm technical system organization data. Certain authors have made impact calculations based on data recorded in experimental farm settings (Flessa et al., 2002) or on a very small number of real-world farms—two farms in Wales (Edwards-Jones et al., 2009) and two farms in Australia (Eady et al., 2011). In France, Gac et al., 2010c

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performed impact assessments on a series of different production systems using data compiled from a livestock farm network counting 350 farms specialized in suckler-beef cattle, classifying them by production system.

Even though the energy use issue, which goes back to the first oil crisis in the 1970s (Pimentel et al., 1973), has been around longer than the GHG emissions issue, it has only been tackled in a modest number of studies. However, non-renewable energy (NRE) consumption is linked to GHG emissions, since the combustion of fossil fuels releases CO_2 (Pervanchon et al., 2002). Attempts to calculate NRE consumption per unit of farm output also revolve around the LCA method (Bochu, 2002; Kraatz, 2012). Most of these assessments have targeted dairy production, chiefly under studies designed to compare organic versus conventional farming systems (Refsgaard et al., 1998; Dalgaard et al., 2001; Gronroos et al., 2006). There is very little literature on fossil fuel consumption for beef production (Galan et al., 2007; Veysset et al., 2010; Capper, 2012).

In remote, mountain or depressed agricultural areas where there is no crop alternative to grasslands, beef cattle production transforms non edible resource (forages) into essential protein and nutrients. Suckler systems play a key role in French livestock farming: one in two French cows is a suckler cow, and cow-calf production yields 60% of the beef consumed in France (Richard et al., 2012). A third of the French national suckler cow herd is found in the depressed-area grassland of the Massif Central. Faced with changing trends in farm-gate prices together with successive reforms to Common Agricultural Policy[1] (EU, 2013), suckler cow farmers have been pushed to increase herd sizes without adapting labour numbers, resulting in a 30%-plus increase in labour productivity within 15 years, while also having to adapt their production systems just to hold onto the same income levels (Charroin et al., 2012). Therefore, in farming impact assessments, economic performance and environmental performance are inseparably linked. However, practically none of the studies cited so far have addressed economic dimensions. The joint assessments performed thus far have employed bio-economic models coupled with environmental models (Veysset et al., 2010; Stehfest et al., 2013).

The aim of this study was to perform a joint assessment on the environmental impacts (GHGs and NRE) and economic performances of suckler beef production systems based on a dataset compiled from real-world farm businesses. The first step was to calculate GHG emissions and NRE consumption for each farm in a known-and-defined livestock farming network (technical and economic performance data) using a methodology adapted to French herbivore systems and operable with on-farm survey data. We went on to analyze the variability and determinants of the results for each gas emitted and each NRE demand source. We then ran a system-wide analysis to compare the organizational structures, production systems and economic performances of the least GHG-emitting farms against the most GHG-emitting farms.

2. Material and methods

2.1. The database: the livestock farm performance monitoring network

The analysis was based on data from a farm monitoring project developed by INRA (French national institute for agricultural research) in the 70s and expanded since then as a national reference tool for technical–economic performance monitoring in livestock farms.

Data are collected yearly on farm: structure, herd performances, unit margins of the individual activity centres (cattle, crops), and all the economic results and ratios. They were completed in 2010 with specific data on GHG emissions and NRE consumption in order to calculate routinely GHG emissions NRE consumption figures for each farm each year, and results are currently available for 2010 and 2011.

The analysis reported here focuses on a constant group sample of 59 farms tracked over two years—2010 and 2011. These 59 farms were specialized in beef cattle and/or mixed crop–beef livestock systems. In order to compare farms, we used data from a specific breed in a unique identified area (same agronomic potential). All these farms breed Charolais cattle and are located in central France, in a grazing area where livestock farms are large and relatively extensive. The farms in our final sample were typically large (averaging 169 ha) grassland-based mixed crop–beef livestock systems (Table A1, supplementary content). Forage area (FA) covered an average 84% of utilized agricultural area (UAA) and was almost exclusively (98%) grassland. The remaining 16% of UAA was dedicated to cash crops, part of which went to on-farm consumption by the herd. At 171 livestock units (LU), mean stocking density was 1.16 LU/ha dedicated to the cattle herd (ha_cattle = forage area plus area of annual crops assigned to cattle feed). Farms in the sample primarily produced store cattle, as fattening animals averaged 37% of total animals. Concentrate consumption per LU was 773 kg—of which 400 kg was produced on-farm with the remaining 373 kg (48%) bought in. The regional dominance of grassland grazed at relatively modest stocking rates logically led to fairly low mineral nitrogen fertilization rates, at 35 kg/N/ha UAA. In 2011, farm income (gross farm product–variable costs–fixed costs) per worker (annual work units [AWU]) was €28,108, with aids and subsidies per AWU at €39,080. Total non-land assets (heads of herd, equipment, buildings and facilities, stocks) held per AWU amounted to €242,705 for a debt ratio (outstanding amount of capital/non-land capital) at around the 30% mark.

These averaged figures conceal broad disparities on all the technical–economic criteria, yet more than mean farm profile. For example, the disparity of animal productivity criteria (kg live weight produced/LU) as well as the stocking rate were not very high (relative standard deviation: respectively 0.14 and 0.17), but we observed a wide disparity in the concentrates consumption and nitrogen fertilization (relative standard deviation: respectively 0.43 and 0.73 for kg concentrates/LU and kg N/ha UAA). It was precisely this broad diversity in structural set-up, size, livestock production system, practices and technical–economic performances that we needed to focus on in order to study the key drivers of GHG emissions and NRE consumption.

2.2. GHG emissions and NRE consumption

Life-cycle analysis offers a transparent, normalized, standardized method for assessing the environmental impacts tied to individual goods or services. It revolves around on defining the production function, the system boundaries, the functional unit (which quantifies the function being studied), the inventory and impact of the resource and consumable flows of the production system, and the allocation methods used to partition the impacts.

2.3. System boundaries

One of the aims of this study is to assess agricultural holding-scale GHG emissions and NRE consumption for suckler beef production over a calendar year. The system boundary therefore

[1] The main aims of the CAP set up in 1962 are: to improve agricultural productivity, so that consumers have a stable supply of affordable food, and to ensure that EU farmers can make a reasonable living thanks to a support scheme. The policy was very effective, productivity greatly increased, so in the face of the food surpluses in the 80's which resulted, the emphasis and support schemes have changed